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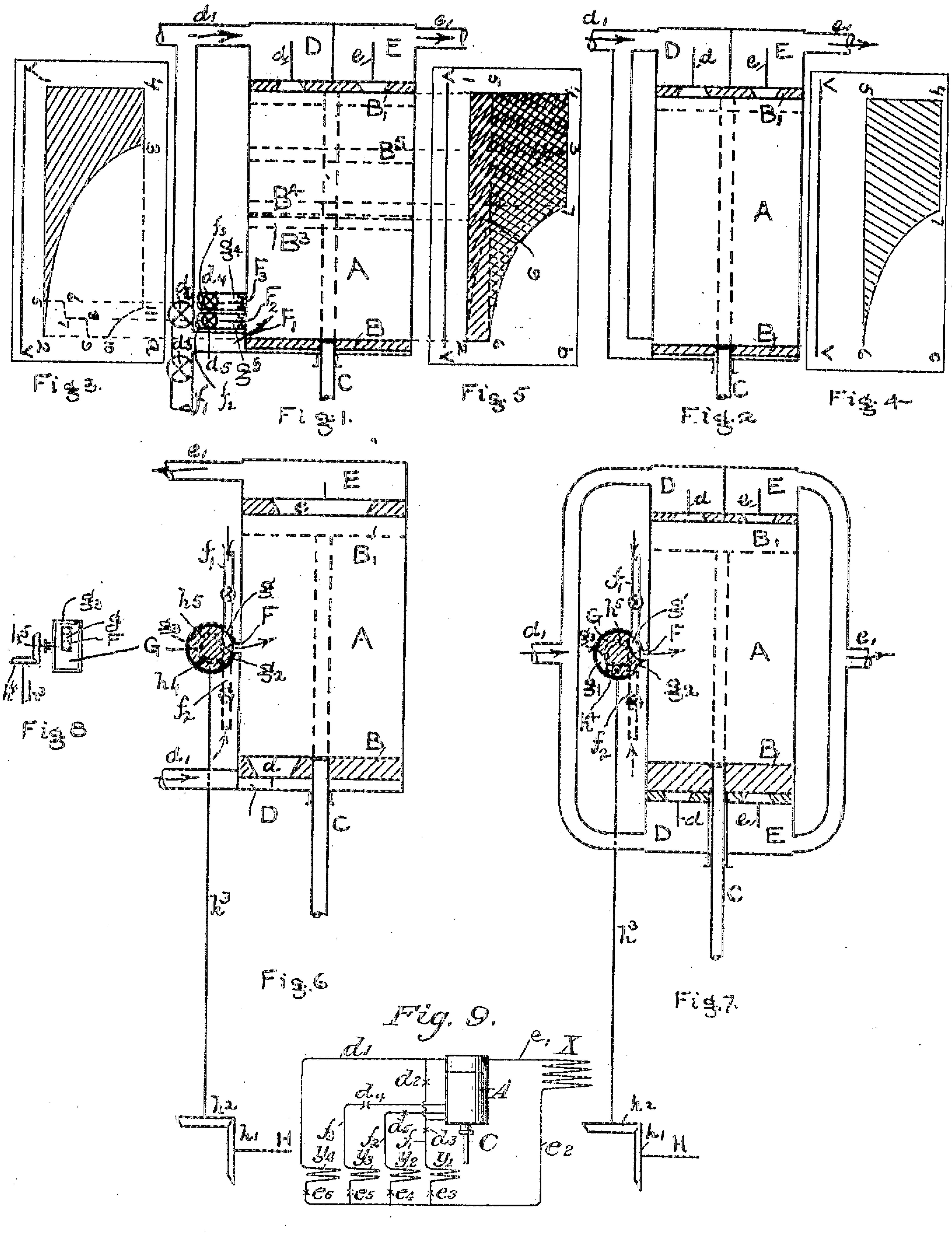
G. T. VOORHEES.
MULTIPLE EFFECT COMPRESSOR.

APPLICATION FILED JULY 30, 1903.



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UNITED STATES PATENT OFFICE.

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MULTIPLE-EFFECT COMPRESSOR.

SPECIFICATION forming part of Letters Patent No. 793,864, dated July 4, 1905.

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To all whom it may concern:

Be it known that I, GARDNER T. VOORHEES, a citizen of the United States of America, residing at Boston, in the county of Suffolk and State of Massachusetts, have invented certain new and useful Improvements in Multiple-Effect Compressors, of which the following is a specification.

My invention relates to refrigerating apparatus, particularly to compressors.

In many applications of refrigeration it is often desirable to maintain in different refrigerators different temperatures of the volatile refrigerant—for example, in a cold-storage warehouse where brine, say, at 0° and 15° Fahrenheit temperature is to be used, in a plant making plate-ice and also can-ice or where a high temperature is required for the first freezing of the plate and a low temperature for the last freezing, also in cooling living-rooms, requiring brine of high temperatures in connection with an ice or cold-storage plant using lower temperatures. Further, in an ice-cream-freezing plant a low temperature may be maintained to freeze the cream, while higher temperatures are employed in freezing ice and cooling storerooms. Likewise a cooling-water plant may require low temperatures besides the higher temperature for cooling the water. In ice-making if the water before going to the cans is cooled, say, from 80° to 32° Fahrenheit thirty-five per cent. would be added to the capacity of the compressor. The additional power required could be furnished without the use of extra steam by making the engine compound. The above cases and many others necessitate the use of two or more different compressors, each operating at a different back pressure, and therefore temperature.

Now the object of my invention is so to modify existing forms of compressors that a single compressor can do refrigeration at two or more different back pressures, and I accomplish this object by providing a compressor with a cylinder having therein two or more back-pressure inlets leading from refrigerators having different temperatures.

The principle of my invention involves Boyle's law. If in a given case a vessel is full of gas at twenty pounds absolute pressure and a like gas at forty pounds pressure is allowed to enter the vessel, the original gas at twenty pounds will be compressed to one-half its volume, have its pressure doubled to forty pounds, and the remaining half of the space in the vessel will be filled by gas at forty pounds pressure. Similarly the pressure of the gas in the vessel could be raised to sixty pounds, then to eighty, or any other higher pressure, if so desired.

In the following diagrammatic drawings, Figure 1 is a sectional view of the preferred form of my invention as applied to compressors. Fig. 2 is a like view of a common single-acting compressor having one-half the volume of the compressor shown in Fig. 1. Figs. 3, 4, and 5 are indicator-diagrams showing the action of the compressors in Figs. 1 and 2 in various ways. Fig. 6 is a modified form of single-acting compressor with my invention applied thereto. Fig. 7 is a double-acting compressor having my invention applied thereto. Fig. 8 is a sectional view of the valve G and its gears shown in Figs. 6 and 7, while Fig. 9 is a diagrammatic view showing my compressor in connection with a high-pressure-gas receiver and several sources of low-pressure gas.

In the drawings illustrating the principle of my invention and the best way now known to me of embodying that principle a compressor-cylinder A has a piston B, provided with a piston-rod C, which is caused to reciprocate by any well-known means. Said cylinder has a suction-valve chamber D and a discharge-valve chamber E. An opening leading from the former into the cylinder is controlled by suction-valve *d*, while an outlet from the cylinder into the discharge-chamber E is controlled by a discharge-valve *e e'*, being a discharge gas-outlet leading to a condenser. (Not shown.) Connecting said suction-valve chamber D with some refrigerator (also not shown) is a suction gas-inlet *d'*. F' F^2 F^3 are ports opening into the cylinder A for auxiliary gas-inlets f' f^2 f^3, the ports F^3 F^2 being controlled by valves of the puppet type g^4 and g^5.

The operation of my invention is as follows: First, let us consider Fig. 1. Valves d^3, d^4, and d^5 are shut, valve d^2 is open, and the compressor is like any ordinary single-acting compressor, the pipe d' conducting from a refrigerator to the cylinder a supply of ammonia-gas at, say, twenty pounds absolute back pressure and the piston B moving from position B′ to B. Said gas at twenty pounds is drawn into the cylinder through pipe d', chamber D, and suction-valve d. The pressure of the gas in the cylinder as the piston B moves inward is represented by line 1 2 on card a, Fig. 3, the line V V representing a perfect vacuum in the cylinder A. The piston at position B changes the direction of its motion and returns toward B′, thereby increasing the pressure of the gas until it reaches the condenser-pressure in the discharge-valve chamber E, the change in pressure in the cylinder being shown by line 2 3 on said card a. The discharge-valve e is forced open, and the compressed gas is discharged through valve e, chamber E, and pipe e' to the condenser, the line 3 4, card a, showing the pressure in the cylinder during this discharge. The piston now starts in the opposite direction, the pressure falls, the valve e immediately shutting and the suction-valve d again opening, the fall of pressure being represented by the line 4 1 of card a. Second, let us consider Fig. 2. This compressor is assumed to be connected at e' with the same condenser as is the first compressor just described and shown in Fig. 1; but its suction gas-inlet d' communicates with a refrigerator supplying ammonia-gas, say, at forty pounds absolute pressure. Further, be it remembered that this second compressor has one-half the capacity of the first compressor. This second compressor has the same mode of operation as the first, its indicator-card being that on card c, Fig. 4. Third, returning to Fig. 1, let us close valves d^2 d^4 d^5 and open valve d^3, d' connecting with gas at twenty pounds pressure and f' connecting with the same supply of gas at forty pounds pressure, as was the second compressor in Fig. 2, and let e' communicate with the same condenser as did the first and the second compressors. Start the piston, as at B′. Gas at twenty pounds pressure will enter the cylinder A, as already described, until the piston nearly reaches position B before opening port F′. Line 1 2 of indicator-card b, Fig. 5, is drawn and indicates the gas as having a pressure of twenty pounds. As the piston finishes its stroke the port F′ is uncovered and the gas under forty pounds pressure from the refrigerator rushes into the cylinder, compressing the gas already therein at twenty pounds pressure to one-half its volume and doubling its pressure to forty pounds, the other half of the cylinder being filled by the incoming gas under forty pounds pressure, there resulting in one cylinder the same quantity of gas at forty pounds pressure as that which was formerly in the first compressor and second compressor at twenty pounds and forty pounds, respectively. This change in pressure is indicated by line 2 6, card b. The piston now moves toward B′, and the gas in cylinder is compressed to the condenser-pressure and valve e opens, the line 6 7 of card b showing the increase of pressure and the point in the stroke of the piston at which the valve e opens. The compressed gas at condenser-pressure is discharged through said valve e, discharge-chamber E, and discharge-outlet e' to the condenser. Line 7 3 4 of said card b indicates the pressure of the gas in the cylinder during said discharge into condenser. The moment the piston B reaches its original starting position and begins to repeat its cycle the discharge-valve closes, a vacuum tends to form, and the pressure falls, as shown by line 4 1 of said card b, until twenty pounds pressure is reached, when valve d opens under the twenty pounds gas-pressure in chamber D. The card 1 2 6 7 4 1 is formed, and from it we learn that when port F′ was uncovered the gas at twenty pounds was raised to a pressure of forty pounds, or that the same action took place as if the piston were moved from B to B^3 and the cylinder full of gas at twenty pounds were compressed to one-half its volume and had twice its pressure—viz., forty pounds—for point 9 is midway between points 5 and 6, the beginning and end of each stroke of the piston, and being on a line indicating forty pounds pressure. That there is twice the amount of gas at forty pounds that there was in the case where only gas at twenty pounds was used is made plain by the line 4 3 7, which is twice as long as 4 3. Evidently by combining the port F′ with the piston B the new multiple-effect compressor can do as much work as was originally done by the combined first compressor in Fig. 1 and the second compressor in Fig. 2. The work expended in the first compressor is proportional to the M. E. P. and the area of the piston, and in the second compressor the work is likewise proportional to its M. E. P. and the area of the piston; but said area is one-half that of the piston of the first compressor. The work expended in the multiple-effect compressor is also proportional to the M. E. P. and the area of its piston. Assuming the condenser-pressure in all above cases is one hundred and seventy pounds absolute, then the M. E. P. in the first compressor is fifty-five pounds and the M. E. P. in the second compressor is sixty-eight pounds. By solving the proportion it appears that the theoretical power to operate the double-effect compressor-cylinder is somewhat less than that of the combined theoretical power required in the first compressor and the second compressor. In actual practice the entire friction of the second compressor in Fig. 2 when running under no load would be saved, so the double-effect compressor would require less power (as appears from an investigation of a number of theoretical cases) than the combined power needed to operate the first and second compressors which the multiple-effect compressor takes the place of—that is, less energy is required by the multiple-effect compressor to furnish to the condenser given quantities of gas at twenty pounds and forty pounds back pressure than if, as heretofore, two separate compressors were used. The power required for the compressor without a load in Fig. 2 is saved, and if there is no second compressor there is saving of space, attendance, oil, and cost of extra compressor. It is evident from Figs. 1 and 3 that if f^3 supplies gas at forty pounds pressure, f^2 at sixty pounds, and f' at eighty pounds, diagram 1 5 6 7 8 9 10 11 3 4 1, Fig. 3, will be formed—in fine, that quantities of gas at different back pressures may be compressed by a single compressor instead of two or more and delivered, for example, to a condenser.

In Fig. 6 I have shown a modification. It is practically the same as the multiple-effect compressor of Fig. 1, except that it has a positively-driven valve G in place of port F' and piston B. Said valve operates in a case g^3 and has a depression g', which by a rotary motion imparted by main shaft H of compressor to the valve G by gearing h' h^2, shaft h^3, gearing h^4 h^5, causes inlets f' and f^2 to open and close when desired.

Fig. 7 embodies the modification of Fig. 6 in a double-acting compressor, the valve G having two depressions g' g' controlling the incoming gas.

In Fig. 9, showing a diagrammatic view of my multiple-effect compressor in connection with a high-pressure-gas receiver and several sources of low-pressure gas, A is said compressor. Leading from the discharge-chamber of said compressor to a high-pressure-gas receiver X is conduit e', while conduit e^2 leads from said high-pressure-gas receiver X to the sources of low-pressure gas, as y' y^2 y^3 y^4, said conduit e^2 being controlled by reducing-valves e^3 e^4 e^5 e^6. These sources of low-pressure gas y' y^2 y^3 y^4 communicate with the compression-cylinder of the compressor A through conduits f', f^2, f^3, and d', respectively. In operation the compressor A takes low-pressure gas *seriatim* from refrigerators y^4 y^3 y^2 y' through the conduits d' f^3 f^2 f', compresses and discharges it into the high-pressure-gas receiver X in the manner already particularly described. The compressed fluid then flows from the high-pressure-gas receiver X through the conduit e^2 and passes the reducing-valves e^6 e^5 e^4 e^3 to the sources of low-pressure gas y^4 y^3 y^2 y'. The cycle of operations is thus completed.

It will be plain that the objects of this invention may be accomplished by other modifications without departing from the spirit of my invention. For example, there may be any desired variations in slots, ports, and valves; further, the suction or discharge valves may be positively driven, or they may be of the puppet type here indicated, and the valve G may be replaced by a valve of any desired construction and may be in any part of the cylinder or its heads and may operate to admit and cut off the gas-supply at any desired point or points of the piston's stroke. In fine, by my invention I make a great saving in the cost of machines, fuel, time, power, oil, labor, space, and the like and I employ a compressor that operates with two or more back pressures in the same cylinder.

What I claim is—

1. In a gas-compressor, the combination of a cylinder; a piston fitting in said cylinder; means to reciprocate said piston in said cylinder; a suction-port opening into said cylinder; a valve governing the same; a discharge-port opening into said cylinder; a valve governing the same; a conduit leading from a source of low-pressure gas to said suction-port and valve; a conduit leading away from said discharge-port and valve to a high-pressure-gas receiver; an additional suction-port opening into said cylinder; an additional suction-valve governing the same; a conduit leading from a source of higher-pressure gas to said additional suction-port and valve, said source being exterior to said compressor; all so arranged and governed that during operation, a body of gas from the low-pressure source is admitted to the cylinder; then a body of higher-pressure gas from the higher-pressure source is admitted to the cylinder, and mixes with the low-pressure gas and partially compresses it; then the mixed and partially-compressed body of gas in the cylinder is further compressed by the piston, and is discharged to the high-pressure-gas receiver.

2. In a gas-compressor, the combination of a cylinder; a piston fitting in said cylinder; means to reciprocate said piston in said cylinder; a suction-port, opening into said cylinder; a valve governing the same; a discharge-port opening into said cylinder; a valve governing the same; a conduit leading from a source of low-pressure gas to said suction-port and valve; a conduit leading away from said discharge-port and valve to a high-pressure-gas receiver; additional suction-ports opening into said cylinder; additional suction-valves governing the same; additional conduits leading to said ports from additional sources of gas at different pressures and at higher pressures than that of the low-pressure source of gas said additional sources being exterior to said compressor; all so arranged and governed that during operation, a body of gas from the low-pressure source is admitted to the cylinder; then a body

of gas from each higher-pressure additional source is admitted *seriatim* to the cylinder, and mixes with the gas in the cylinder, and partially compresses it; then the mixed and partially-compressed body of gas in the cylinder is further compressed by the piston, and is discharged to the high-pressure-gas receiver.

3. In a gas-compressor, the combination of a cylinder; a piston fitting in said cylinder; means to reciprocate said piston in said cylinder; a suction-port opening into said cylinder; a valve governing the same; a discharge-port opening into said cylinder; a valve governing the same; a conduit leading from a low-pressure refrigerator to said suction-port and valve; a conduit leading away from said discharge-port and valve to a condenser; an additional suction-port opening into said cylinder; an additional suction-valve governing the same; a conduit leading from a higher-pressure refrigerator to said additional suction-port and valve; all so arranged and governed that during operation, a body of gas from the low-pressure refrigerator is admitted to the cylinder; then a body of higher-pressure gas from the higher-pressure refrigerator is admitted to the cylinder, and mixes with the low-pressure gas, and partially compresses it; then the mixed and partially-compressed body of gas in the cylinder is further compressed by the piston, and is discharged to a condenser.

4. In a gas-compressor, the combination of a cylinder; a piston fitting in said cylinder; means to reciprocate said piston in said cylinder; a suction-port, opening into said cylinder; a valve governing the same; a discharge-port opening into said cylinder; a valve governing the same; a conduit leading from a low-pressure refrigerator to said suction-port and valve; a conduit leading away from said discharge-port and valve to a condenser; additional suction-ports opening into said cylinder; additional suction-valves governing the same; additional conduits, leading to said ports from additional refrigerators at different pressures and at higher pressures than that of the low-pressure refrigerator; all so arranged and governed that during operation, a body of gas from the low-pressure refrigerator is admitted to the cylinder; then a body of gas from each higher-pressure additional refrigerator is admitted *seriatim* to the cylinder, and mixes with the gas in the cylinder, and partially compresses it; then the mixed and partially-compressed body of gas in the cylinder is further compressed by the piston, and is discharged to a condenser.

In testimony whereof I affix my signature in presence of two witnesses.

GARDNER T. VOORHEES.

Witnesses:
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